A new look at outcomes after infrainguinal bypass surgery: Traditional reporting standards systematically underestimate the expenditure of effort required to attain limb salvage

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Background: **Graft patency, limb salvage, and mortality are the traditional means of assessing the outcome of infrainguinal bypass surgery (IBS). However, these measures underestimate patient morbidity and fail to consider the entire spectrum of treatment required to restore the patients to their premorbid state. The aim of this study was to quantify the efforts required to achieve limb salvage by assessing three nontraditional outcomes: (1) index limb reoperation rate in 3 months, (2) hospital readmission rate in the first 6 months after IBS, and (3) wound-healing time.**

Methods: **We retrospectively analyzed 318 IBSs performed at a single institution. Repeat operations for limb or graft-related problems and readmissions within 6 months of the initial operation were recorded. When available, wound-healing time was determined. Pertinent demographics and comorbidities were subjected to univariate and multivariate analysis to determine risk factors for adverse outcomes.**

Results: **Seventy-two percent of patients underwent IBS for critical limb ischemia (CLI), and 84% had below-knee popliteal or distal bypasses. Among those who underwent IBS for CLI, 48.9% of patients required at least one reoperation within 3 months. Within 6 months, 49.3% of patients required hospital readmission. Time to heal exceeded 3 months in 54% of patients. After multivariate analysis, tissue loss and minority status were significant risk factors for reoperation within 3 months. Tissue loss and renal failure increased the odds for readmission within 6 months. Diabetes was the sole risk factor for prolonged wound healing.**

Conclusions: **IBS for limb salvage is often complicated by prolonged recovery and multiple reoperations and readmissions. Traditional reporting standards for limb salvage operations need modification to reflect the true outcome of such procedures. (J Vasc Surg 2004;39:330-5.)**

Because of improvements in surgical technique and perioperative care, an aggressive approach to limb salvage for patients with critical limb ischemia (CLI) has been widely adopted.[1] The success of IBS traditionally has been measured solely in terms of mortality, graft patency, and limb salvage rates.[2] However, these traditional measurements underestimate patient morbidity and fail to consider the entire spectrum of treatment that is required to restore patients to their premorbid state.

This study was conducted to quantify the effort required to treat limb ischemia by assessing three nontraditional outcome measures: index limb reoperation rate within 3 months of IBS, hospital readmission rate in the first 6 months after leg bypass, and wound-healing time. We also attempted to identify, by analysis of multiple preoperative patient factors and characteristics, those individuals who are at particularly high risk for adverse outcomes.

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METHODS

The study population consisted of all patients who underwent IBS for peripheral arterial occlusive disease at the University of Arizona from 1990 to 2002. Infrainguinal bypass operations for traumatic injuries were excluded from the study. We also excluded those patients who underwent initial IBS elsewhere.

Data were obtained from retrospective review of medical records. Demographic information, as well as pertinent medical conditions such as diabetes mellitus, renal failure, and cardiovascular disease, was recorded. Operative indications were categorized into claudication, rest pain, and ischemic tissue loss. During the study period, IBS for claudication was reserved for patients with significant lifestyle limitation who had been refractory to nonoperative treatment, including smoking cessation, exercise regimen, and medical treatment. Therefore, the majority (72%) of our IBS were performed for indication of CLI.

Of the 315 vascular reconstructions, 285 (91%) were performed using autogenous venous conduits. These conduits included leg (greater or lesser saphenous) veins, arm (basilic or cephalic) veins, or spliced vein conduits as required based on suitability and available length. Synthetic

Table I. Demographics

	No. of patients	*%*
Age >75 y	104	33
Female	130	41
Caucasian	211	67
Hispanic	72	23
Native American	26	8
African American	6	2
Diabetes mellitus	154	49
Renal failure	53	17
Congestive heart failure	51	16
Coronary artery disease	141	44
Hyperlipidemia	80	25
Previous stroke	40	13
Previous smokers	122	38
Current smokers	87	27
Previous PVD operations	90	28

grafts were primarily employed in the femoral to above-knee popliteal artery position, with the exception of a modest number of cases in which PTFE with adjunctive Taylor patch,[3] PTFE Distaflo (Bard-Impra Inc, Tempe, Ariz) grafts, or composite grafts were used for infrageniculate bypasses because of a lack of autogenous vein. There were only 13 limbs that were bypassed with nonautogenous grafts in patients with either minor or major tissue loss.

The patients with CLI, either rest pain or ischemic tissue loss, were further analyzed to determine the nontraditional outcomes. End points for each nontraditional outcome were selected before data collection and review based on our experience and are described in the following paragraphs.

Early and intermediate reoperation was defined as any operative procedure performed within 3 months of the initial vascular reconstruction. Subsequent wound debridements and minor amputations for infected or ischemic lesions that required return to the operating room were also included. However, those procedures performed at the bedside or in clinic settings were excluded. Grossly infected tissue was surgically debrided to control infection first. After the revascularization, further debridements were performed as necessary to obtain a healed foot. Such procedures included redebridement alone; additional toe amputations; transmetatarsal amputation, Chopart, and Lisfranc amputations; and even free flaps if needed to obtain a healed foot or to cover large wound defects. Well-demarcated dry gangrenous toes were amputated and closed if possible at the time of the index revascularization. If there was not clear demarcation, we waited for at least 5 to 7 days for the foot to declare itself before performing amputation or debridements.

Early-intermediate hospital readmission was defined as any admission within 6 months of the initial index IBS. The number of readmissions and cumulative length of stay were noted. We also determined and recorded whether any readmission was related to the initial IBS itself or to associated medical or nonvascular comorbidities.

Table II. Summary of specific perioperative complications for CLI patients

Complications	*No. of patients*	*%*
Wound complications	26	11.4
Graft thrombosis	8	3.5
Myocardial infarction	9	3.9
Hemorrhage	3	1.3
Stroke	3	1.3
Death	3	1.3
Others	10	5.7
Total	44	19.2

We reviewed the office charts, when available, to assess the course of wound healing. More than 50% of patients had close follow-ups subsequent to their IBS, with clear documentation of their wound-healing courses. Prolonged wound healing was defined as a period exceeding 3 months to achieve complete wound healing.

Data were then processed using the SPSS program (SPSS Inc, Chicago, Ill). Descriptive statistics were used to calculate relative risks or odds ratios (OR). Chi-square was used to calculate P value to assess statistical significance ($P < .05$ was considered significant). Multiple logistic regression models with stepwise analysis were used to perform multivariate analysis. Cox regression survival analysis was used to generate the time for wound-healing curves.

RESULTS

There were 318 IBS procedures meeting inclusion criteria; initial inpatient charts were available for complete review in 315 cases. Demographic data are summarized in Table I. Approximately 72% of patients (n = 229) underwent IBS for CLI as defined by the presence of ischemic rest pain or tissue loss. Infrageniculate bypass was required in 84% of patients, of whom 13% had popliteal artery as the inflow source and 52% had tibial or pedal outflow targets.

The incidence of perioperative complications, reoperation within <3 months, and readmission within 6 months were calculated for the patients with claudication, rest pain, and ischemic tissue loss. The results are summarized in Fig 1.

We focused our analysis on those patients with CLI. Perioperative complications occurred in 19.2% of patients with CLI. Perioperative wound complications were defined as either ischemic or infectious wound problems that required operative management during the initial hospital stay. Table II summarizes the incidence of specific complications. The median of the initial hospital length of stay was 9 (range, 3 to 92) days.

Intermediate postoperative outcomes and complications were also carefully evaluated and analyzed. Within 3 months of the initial IBS, 48.9% of patients underwent at least one additional operation. The variety and scope of operative procedures required during this intermediate postoperative period are summarized in Table III. These operations included free flaps to cover large wound defects,

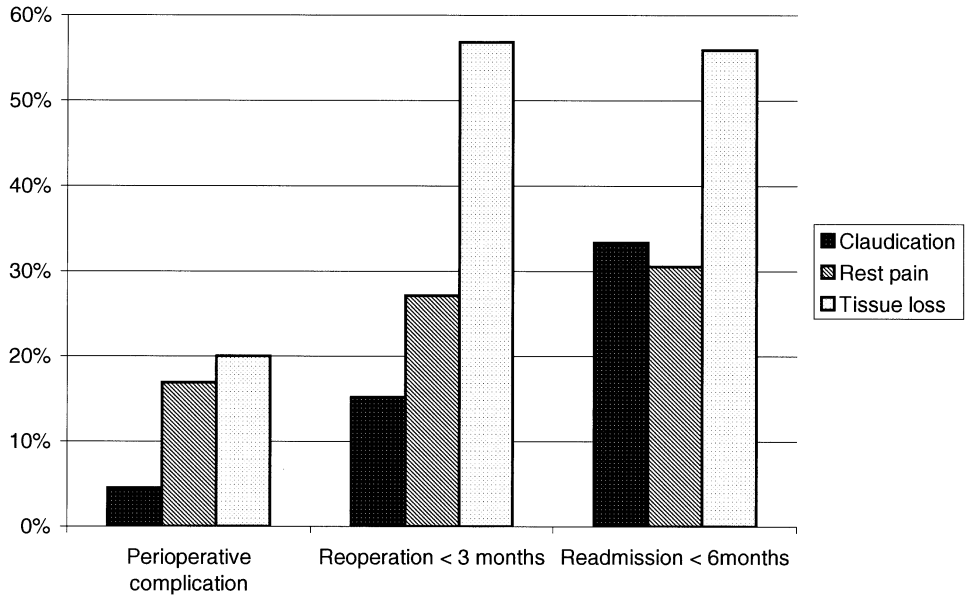

Fig 1. Incidence of perioperative complications, reoperations, and readmissions.

Table III. Reoperation by <3 months

Procedure	*No. of patients*	*%*
Minor amputation	51	22.3
Debridement of ischemic wounds	36	15.7
Skin grafting	21	9.2
Bypass graft revision	19	8.3
Surgical wound management	19	8.3
Major amputation	8	3.5
Redo bypass graft	4	1.7
Other	30	13.1
Total	112	48.9

Table IV. Factors leading to readmissions

Reasons for readmissions	*CLI patients*	*Claudicants*
Related to the initial IBS	136	13
Contralateral limb problem	18	7
Cardiac issues	17	4
Pneumonia	9	0
Renal failure and fistula complications	8	0
Sepsis	7	0
Pulmonary embolus	2	0
Gastrointestinal problems	4	1
Hypoglycemia	2	0
Syncope	1	1
Stroke	1	0
Unrelated operations	4	3
Total admissions	209	29

ligation of AV fistulae after in situ bypass, graft revision procedures for stenosis, amputations and debridements, contralateral limb procedures, and unrelated operations.

The overall hospital readmission rate for the CLI patients within 6 months of the original index revascularization was 49.3%. The cumulative median length of stay for all readmissions was 11 days. Approximately two thirds of all readmissions were directly attributable to issues related to infection or nonhealing of the foot among CLI patients. Table IV summarizes reasons for hospital readmission, comparing the CLI patients and claudicants. The majority of IBS-related admissions for claudicants was due to graft stenosis or thrombosis.

Using SPSS statistical software, numerous pertinent preoperative characteristics summarized in Table I were examined to determine the respective odds ratios (OR) for the development of the perioperative complications and adverse nontraditional outcomes. The results are detailed in Figs 2 to 5 (online only).

A history of congestive heart failure, hyperlipidemia, and CAD all increased the risk of perioperative complications by nearly two-fold in univariate analysis. After multivariate analysis, however, only CAD was found to be statistically significant, with OR of 2.35 and *P* value of .014. Advanced age, gender, diabetes, renal failure, and previous leg bypass were not associated with an increased risk for perioperative complications.

Univariate analysis revealed that operations for ischemic tissue loss (OR 3.5), minority status (OR 2.6), renal failure (OR 2.5), and diabetes mellitus (OR 1.9) were associated with significantly increased risk for reoperation in the intermediate postoperative period. After multivariate analysis, however, only tissue loss and minority status were statistically significant (OR 3.1 and 2.2; *P* values, .001 and .007, respectively).

Ischemic tissue loss (OR 2.9), renal failure (OR 2.8), and diabetes mellitus (OR 2.3) were also the leading risk

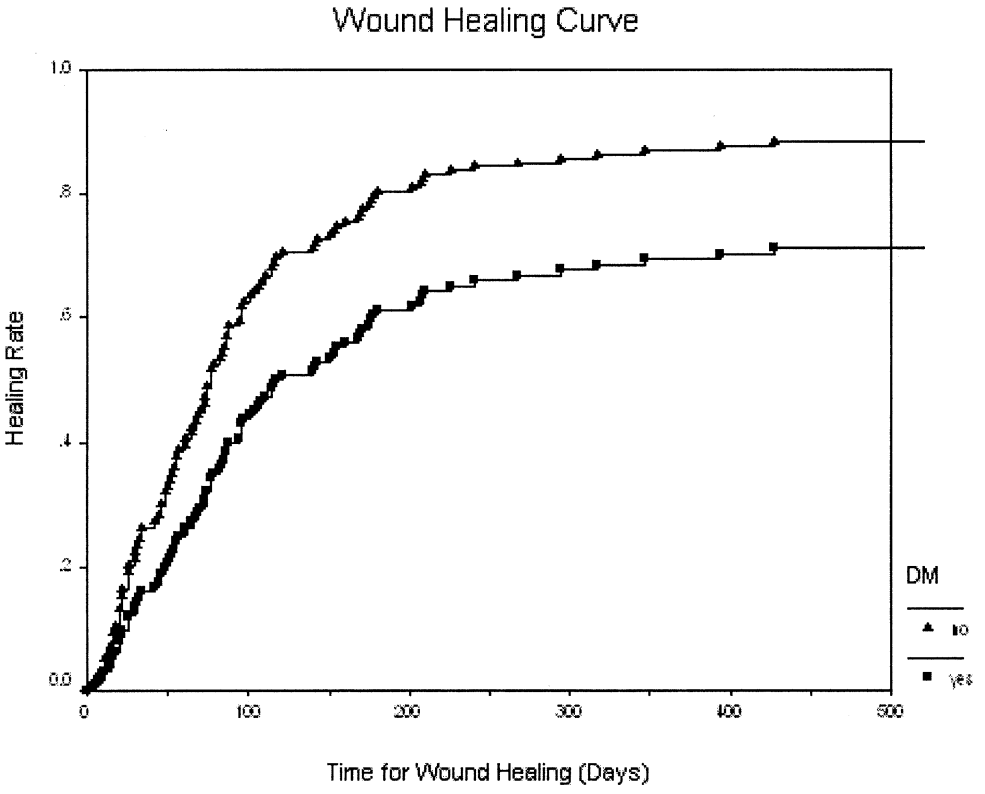

Fig 6. Wound healing curves.

factors for readmission within 6 months in the univariate analysis. Minority status increased the risk for the reoperation within 3 months, but not for readmission within 6 months. After multivariate analysis, tissue loss and renal failure were found to be significant risk factors, with OR of 2.8 and 2.3 (*P* values .004 and .021, respectively).

Among the CLI patients, 76% (174) of patients underwent arterial bypass for ischemic tissue loss. Of this patient cohort, 137 office charts were available to assess the long-term follow-up with respect to wound healing. There were 17 patients who never healed the wound during the follow-up period, and 13 limbs required major amputations (below-knee or above-knee amputations). Only 63 patients (46%) required <3 months to achieve complete wound healing. The median wound-healing time was 86 days. The risk factors associated with prolonged wound-healing time were diabetes mellitus and hypertension, based on the univariate analysis. After multivariate analysis, only diabetes was associated with prolonged wound healing (OR 3.42, *P* value .003). Cox regression survival analysis was used to analyze the wound healing time for diabetic and nondiabetic patients (Fig 6).Table V summarizes the significant risk factors for adverse outcomes identified by multivariate analysis.

Table V. Multivariate analysis: risk factors for adverse outcomes

Outcomes	*Risk factors*	*Odds ratios*
Reoperation < 3 mo	Ischemic tissue loss	3.1
	Minority status	2.2
Readmission < 6 mo	Ischemic tissue loss	2.8
	Renal failure	2.3
Delayed wound healing	Diabetes mellitus	3.4

DISCUSSION

The outcomes of IBS traditionally have been reported and assessed in terms of graft patency, limb salvage, and patient survival rates. In the present study, perioperative mortality was 0.9%, and 30-day graft thrombosis rate was 3.1%. In our previously published series, the 5-year limb salvage rate was 91%, and the 5-year assisted-primary graft patency rate was 72%.[4] Cost analysis revealed that limb salvage–related expenses over 5 years, including those generated by graft surveillance and maintenance (revisions) were equivalent to the cost of primary major limb amputation.[4] However, these traditional measures and financial analyses inaccurately depict the true scenario for a patient

with CLI requiring revascularization (IBS). We believe that these traditional reporting standards systematically underestimate the expenditure of effort and associated patient morbidity that are involved in the management of CLI patients.

Recently, functional outcome assessments of IBS have been published by Abou-Zamzam et al[5] from the Oregon group. Those investigators assessed the preoperative and postoperative ambulation status and independence of patients. They concluded that preoperative independence and ambulation were the best predictors of postoperative independence and continued ambulation.

Patient recovery after IBS for limb salvage has been reported by Nicoloff et al,[6] also based upon the Oregon experience. That group emphasized that an ideal outcome, as defined by the expectations of a patent graft, healed wound, no need for reoperation, independent living status, and continued ambulation was extremely difficult to achieve in such patients. Only a small fraction (<25%) of their patients met these basic criteria.[6]

There is a paucity of reliable information in the vascular surgical literature that realistically depicts the typical course that a CLI patient actually faces in the early and intermediate postoperative period once one embarks on the uphill and difficult path of limb salvage. In this study, we attempted to accurately define the expenditure of effort and the complications and difficulties encountered by the patient and the surgical team to achieve limb salvage in the early and intermediate postoperative period. We analyzed in some detail three specific, nontraditional outcomes measures: (1) reoperation within 3 months, (2) readmission in the first 6 months after the index revascularization operation, and (3) time to complete wound healing.

At least one reoperation was required in 48.9% of patients for limb- and graft-related problems within 3 months of the index revascularization. The dominant risk factor for reoperation was the presence of ischemic tissue loss. The majority of such patients require minor procedures related to their initial ischemic wounds, such as debridements and minor amputations.

Hospital readmissions within 6 months were required in 49.3% of patients. By multivariate analysis, ischemic tissue loss and renal failure increased the likelihood of readmission. Although two thirds of these readmissions were specifically due to issues relating to their ischemic limb, it is worth noting that the remaining one third resulted from complications arising from associated medical comorbidities. This confirms the significance of comorbidities in patients with CLI that require ongoing care.

Less than half of those patients presenting with ischemic tissue loss achieved complete wound healing within a 3-month period. In this study, diabetes proved to be the dominant risk factor for the prolonged wound healing. The pathophysiologic relationship between diabetes and impaired wound healing is complex. Vascular, neuropathic, immunogenic, and biochemical abnormalities all contribute to a diminished capacity for tissue repair.[7] Diabetic patients, particularly those with renal failure, often suffer nonhealing wounds despite patent, functional bypass grafts.

Numerous publications have suggested that the presence of renal failure interferes with wound healing. In a study published by Johnson et al[8] from South Florida, failure of foot salvage in renal failure patients was related to poor wound healing, such as ongoing ischemia or uncontrollable infection, despite a functional graft. These patients may ultimately require major limb amputation despite ongoing graft patency.[9] In the present report, although renal failure was a major risk factor for repeat operation and readmissions, it was not a major risk factor for prolonged wound healing.

Coronary artery disease was the leading risk factor for perioperative complications. Increased perioperative morbidity and mortality for patients with preexisting cardiac disease has been reported elsewhere.[10] A recent publication confirms poorer outcomes for patients taking furosemide preoperatively.[11] By univariate analysis, congestive heart failure was one of the risk factors for increased perioperative complications; however, it failed to remain as a statistically significant risk factor after multivariate analysis.

Our perioperative wound complication (11%) is significantly less than the 40% rate published elsewhere.[12] This is because we only included wound complications that required surgical management in the operating room. Minor wound issues managed in outpatient clinic with simple debridement and dressing changes were not considered major wound complications.

We were unable to include in this study a quantification of the time that was expended in the care of ischemic and infected wounds and the number of outpatient office visits that were needed to provide ongoing outpatient wound management. In addition, most patients undergoing IBS for limb-threatening ischemia are nearing the end of life. The previously reported 5-year survival rate for CLI patients has ranged from 12% to 64%, with a mean of 45% to 50%.[6] Therefore, many of these patients spend a significant portion of their remaining life attending to their ischemic limb needs. It is thus important to assess quality of life issues for CLI patients to provide them optimal care.

CONCLUSIONS

This study, of course, is limited by its retrospective nature and consists of high-risk patients who were referred to a tertiary care center with an interest and experience in CLI. However, by analyzing three nontraditional outcome measures, we believe that the effort required to achieve limb salvage has been quantified in a more scientific manner. To achieve limb salvage, ongoing and extensive medical and surgical interventions must be continued for a prolonged interval after the initial operation. Even within the early to intermediate postoperative convalescent period, patients should be informed that multiple operations and readmissions are commonplace, are to be expected, and are, in fact, the norm. For some of these individuals, the option of major limb amputation, rather than limb salvage, needs to be at least considered and carefully discussed,

given the anticipated prolonged recovery. This information may be of clinical utility when counseling CLI patients by providing a more realistic picture of what a patient may expect to encounter once the path for the limb salvage is chosen. At the same time, the traditional reporting standards for limb salvage operations need modification to reflect the true outcome of such procedures.

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DISCUSSION

Dr Gregorio A. Sicard (St. Louis, Mo). Of the patients who had more than 3 months, or 3 months or longer, for wounds healing, for how many of those was the reoperation an amputation? In other words, could you predict, based on the time that it would take to heal, which one of those would lead to an amputation rather than reoperation or skin grafting, etc?

Dr. Joseph L. Mills, Sr. We didn't focus on that, but very few of the reoperations were major limb amputations. Our amputation rate for the first 6 months was between 3% and 5%. So it's very low. But we had some patients whose wounds never healed. There were actually, I think, 8 or 10 individuals who either died with patent graft or lived in a wheelchair the rest of their life and didn't heal their wounds at all. And then we had a couple who just chronically came back to clinic with a tiny ulcer that we could never get to heal and the patients were extremely frail, so we let them live with their nonhealing ulcers.

But what we tried to focus on in this paper was not so much limb amputation rate, but something, I think, that's been neglected, and that is what these patients go through as we try to get them to the point where they heal. And we started to wonder in some patients if it's worth it if they have 2 years of life left and you spend a year trying to get this ulcer to finally heal. Is that effort cost effective?

Dr Mark R. Nehler (Denver, Colo). How did you stratify the tissue loss in the patients with Fontaine IV—what was minor and what was major? Does this have a big impact on the outcomes and recurrent surgeries?

Dr. Mills. I think it does. One particular group that we've noted trouble with is heel ischemia in renal failure patients. So if a patient had significant heel ischemia, that was considered major tissue loss. Minor was an ulcer or just gangrene of the tip of the toe. If the gangrene involved the forefoot or three toes or more, that was considered major.

Dr Frank J. Veith (Bronx, NY). This is a very nice paper, and you have documented very clearly something we have known now for 20-plus years, that this is a difficult business. It is not simple to save limbs that have established gangrene.

The implication that you have made in the presentation was that there are some patients who should have a primary amputation. And we have looked at this very hard and very long over the years and have not been able to come up with a criterion, other than perhaps extensive gangrene in the presence of renal failure. But all other factors seem not to preclude limb salvage. So I wonder if you have found criteria by which you could say: yes, we should do a primary amputation.

We do tell our patients just what you tell them, namely, this is not a simple business, but we still think it is worthwhile. And of course, cost issues and DRG length-of-stay issues as we presented yesterday are still very important in this area.

I wonder how you respond to these comments?

Dr Mills. I think our practice is much like yours. We're still trying to search for some algorithm that will tell us which patient really should have an amputation. But if you look at the quality of life in many of these individuals, if they have an amputation, it's even worse.

So I think that in most of these patients it is worth this process. But I think you need to tell them up front what lies ahead. Our finding that struck us was that, in every one of those nontraditional outcomes that we looked at, congestive heart failures was one of the risk factors for reoperation, perioperative complication and readmission within 6 months. And that implies to me that maybe it's limb edema or perhaps even low cardiac output that prohibits wound healing, but maybe we could do a better job targeting those patients. Obviously, we don't take someone to the operating room with uncontrolled congestive heart failure, but maybe these people deserve a little bit of extra attention to try to get them to heal. But we have not yet been able to develop more specific criteria to predict those patients who would be best served by primary amputation because those patients also do quite poorly and there are lots of studies that show that.